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Evaluation of Sustainable Design Practices in Architecture based on the application of AHP

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Abstract

This research paper explores the evaluation of sustainable design practices in architecture using the Analytic Hierarchy Process (AHP). The study aims to identify the most effective sustainable design practices by structuring the decision-making process into a hierarchy of goals, criteria, and alternatives. Criteria such as energy efficiency, material sustainability, water conservation, indoor environmental quality, and site impact are assessed through pairwise comparisons to establish their relative importance. By calculating priority weights and ensuring consistency in the evaluations, the study synthesizes the results to rank the sustainable design alternatives. The application of AHP provides a structured framework that integrates both quantitative data and expert judgments, ensuring transparency and rationality in decision- making. This method not only facilitates a comprehensive evaluation of sustainable design practices but also highlights the importance of balancing multiple criteria to make informed and justifiable decisions in architectural sustainability. The findings offer valuable insights for architects, planners, and policymakers aiming to enhance the sustainability of built environments, offering a framework for prioritizing key metrics and guiding future research to quantify limits and establish best practices for sustainable development.

Keywords: *Sustainable Design Evaluation, Architecture, Multi-Criteria Decision-Making, Sustainable Architecture, Analytic Hierarchy Process (AHP)*

1.0 Introduction

Sustainable design in architecture is a comprehensive approach that aims to minimize the environmental impact of buildings while enhancing the health and well-being of occupants. It integrates principles of energy efficiency, resource conservation, and environmental stewardship throughout the building's lifecycle, from design and construction to operation and decommissioning. Buildings are responsible in global energy consumption and greenhouse gas emissions, making up nearly 40% of energy use and similar share of CO_2 emissions (Buckleyet al., 2021). Improving carbon footprint of buildings, conserving natural resources and promoting healthy lifestyle are essential steps toward creating sustainable living environment.

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Key components of these principle include energy-efficient buildings, utilizing the power of cooling, natural light and insulation like HVAC systems or incorporate building management systems (BMS) which enable optimal performance (Abo, 2021). Key strategies include the use of renewable energy sources, such as solar and wind power, to reduce reliance on fossil fuels (Aien & Mahdavi, 2020); the selection of sustainable materials, which are often locally sourced, recycled, or rapidly renewable, to decrease environmental footprint; and the implementation of water conservation measures, such as low-flow fixtures and rainwater harvesting systems (Shajal, 2023). Indoor environmental quality is also a critical aspect of sustainable design, achieved through ample natural lighting, ventilation, and the use of non-toxic, low-emission materials. Building materials are significant major sources of volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs) and carbonyl compounds (including formaldehyde) as indoor air pollutants that easily vaporize under normal conditions (David & Niculescu, 2021; Ritcher et al., 2021). Thus, green or bio-composite materials have acquired attention due to their characteristics as bio-degradable and composability in the construction industry (Abhiram et al., 2021). They are affected by bacteria, turning them into small substances without any harm to the environment (Khoshnava et al., 2020). According to Dizdaroglu (2022) and Wang et al., (2024), sustainable design practices also focus on minimizing the disruption to the natural landscape, promoting biodiversity, and ensuring connectivity to public transportation and community amenities. By addressing economic, social, and environmental sustainability, sustainable design in architecture not only reduces negative impacts on the environment but also creates healthier, more productive spaces for occupants and contributes to the resilience and sustainability of communities (Murtagh et al., 2020).

1.1 Challenges in Evaluating and Prioritizing Sustainable Design Practices

Architects are increasingly turning to sustainable design to create buildings that are not only beautiful and functional but also environmentally responsible. As the world population grows, the demand for housing is rising, leading to increased environmental pressures. Sustainable practices are essential to balance human needs with ecological preservation. Zhang et al., (2022) and Zhong et al., (2022) pointed the potential of sustainable architecture to address pressing global issues. By adopting sustainable design principles, architects can play a crucial role in mitigating these challenges and creating a more sustainable future (Mba et al., 2024). Overcoming these challenges necessitates concerted efforts through education, capacity building, incentives, and the systematic integration of green principles into public infrastructure (Adewale et al., 2024).

Evaluating and prioritizing sustainable design practices in architecture presents several complex challenges. One significant hurdle is the diverse range of criteria and metrics involved, encompassing energy efficiency, water conservation, material sustainability, indoor environmental quality, and social and economic impacts. Balancing these criteria often involves conflicting priorities, such as choosing between a highly durable material with a high initial environmental impact and a less durable, low-impact alternative (Akadiri, P. O., & Olomolaiye, P. O., 2012). Quantifying environmental impacts accurately requires comprehensive and often hard-to-obtain data for life cycle assessments. As mentioned by De Gaulmyn, C., & Dupre, K. (2019), cost considerations add another layer of complexity, as the initial expenses for sustainable materials and technologies can be higher, necessitating careful evaluation of long-term savings and environmental benefits.

Diverse stakeholder perspectivesalso complicate the process, as architects, builders, clients, and regulatory bodies may have different priorities. According to Markelj, J., et. al. (2014), Motawa, I. (2013), Olukoya, O. A. (2020) and Pons-Valladares, O., (2020), regulatory compliance, keeping pace with rapid technological advancements, and ensuring the availability of reliable data further add to the challenge. Additionally, predicting the long-term performance of sustainable practices involvesuncertainty, influenced by factors like climate change and evolving user needs. According to Ashour, M., Mahdiyar, A., & Haron, S. H. (2021), integrating sustainable practices while respecting cultural and aesthetic values without compromising sustainability goals is another delicate balance. Addressing these challenges requires a holistic, informed approach that combines quantitative analysis with stakeholder engagement and ongoing updates to knowledge and practices.

1.2 Introduction to AHP and its Application in Decision Making

The Analytic Hierarchy Process (AHP) is a structured decision-making methodology developed by Thomas L. Saaty that helps evaluate and prioritize options based on multiple criteria. In architecture, AHP is particularly useful for assessing sustainable design practices, which often involve balancing complex and sometimes conflicting factors such as energy efficiency, material sustainability, water conservation, indoor environmental quality, and site impact.

AHP (Analytic Hierarchy Process) works by first defining the problem and objective, such as selecting the most effective sustainable design practices. It structures the decision into a hierarchy of goals, criteria, and alternatives, such as energy efficiency and material sustainability. Pairwise comparisons are made to assess the relative importance of each criterion, establishing priority weights, followed by calculating a consistency ratio to ensure the comparisons are reliable. The results are synthesized to determine overall rankings, guiding the final decision. In sustainable design, AHP evaluates factors like energy efficiency, material sustainability, water conservation, indoor environmental quality, and site impact. The benefits of AHP include providing a structured framework, integrating quantitative and qualitative data, enhancing decision transparency and rationality, and ensuring consistent evaluations. In summary, AHP offers a systematic approach to evaluate sustainable design practices, balancing multiple criteria for informed decisions.

1.3 Overview of Sustainable Design Practices in Architecture

Sustainable design practices in architecture aim to minimize environmental impact and enhance occupant well-being through various strategic elements (Feria, M., & Amado, M., 2019). Energy efficiency is a cornerstone, achieved using energy-efficient systems and appliances, passive design strategies like natural ventilation and solar orientation, and the integration of renewable energy sources such as solar panels and wind turbines. Material selection also plays a critical role, prioritizing sustainable, low-impact materials, preferably locally sourced to reduce transportation emissions, and considering the life cycle impact of materials to ensure they can be reused or recycled effectively. Water conservation is another key element, implemented through water-efficient fixtures, greywater systems for non-potable uses, rainwater harvesting, and landscaping with native or drought-tolerant plants. As mentioned by Ford, B., & Wilson, R. (2006), indoor environmentalquality (IEQ) is enhanced by ensuring adequate natural light and ventilation, using low-VOC materials to improve air quality, incorporating air purification systems, and designing for bothacoustic and thermal comfort. The impact on the site and its surroundings is minimized by protecting local biodiversity, managing stormwater runoff, reducing impervious surfaces, and ensuring connectivity to public transportation and amenities. Volatile Organic Compounds (VOCs), a diverse group of chemicals including alcohols, aliphatic and aromatic hydrocarbons, aldehydes, ketones, esters, and halogenated hydrocarbons, can have serious health implications. Some VOCs are known carcinogens, mutagens, and teratogens. Furthermore, other construction materials like artificial fibers, flame retardants (polyfluoroalkyl substances (PFAS)), and plasticizers (including PBDEs, phthalates and OPEs) can release harmful substances into the air and accumulate in the body over time (D Amico et al., 2020; Almroth & Athey, 2022).

Waste reduction strategies include construction waste management to minimize landfill contributions, designing for adaptability and disassembly to extend the building's lifecycle, and promoting recycling and composting (Grierson, D., & Moultrie, C. M., 2011). Sustainable landscaping involves designing landscapes that require minimal water, fertilizers, and pesticides, incorporating green roofs and walls, and promoting urban agriculture and community gardens. Social sustainability ensures that buildings are accessible for all users, foster community interaction, and incorporate cultural and historical elements into the design. Lastly, economic sustainability focuses on designing for long-term value, reducing operational costs through low-maintenance and efficient systems, and considering the economic impact on the local community (Grover, R., Emmitt, S., & Copping, A., 2020). These elements collectively create buildings that are environmentally responsible, resource-efficient, and provide healthy, inclusive environments for their occupants.

1.4 Previous Applications of AHP in Architecture and Design

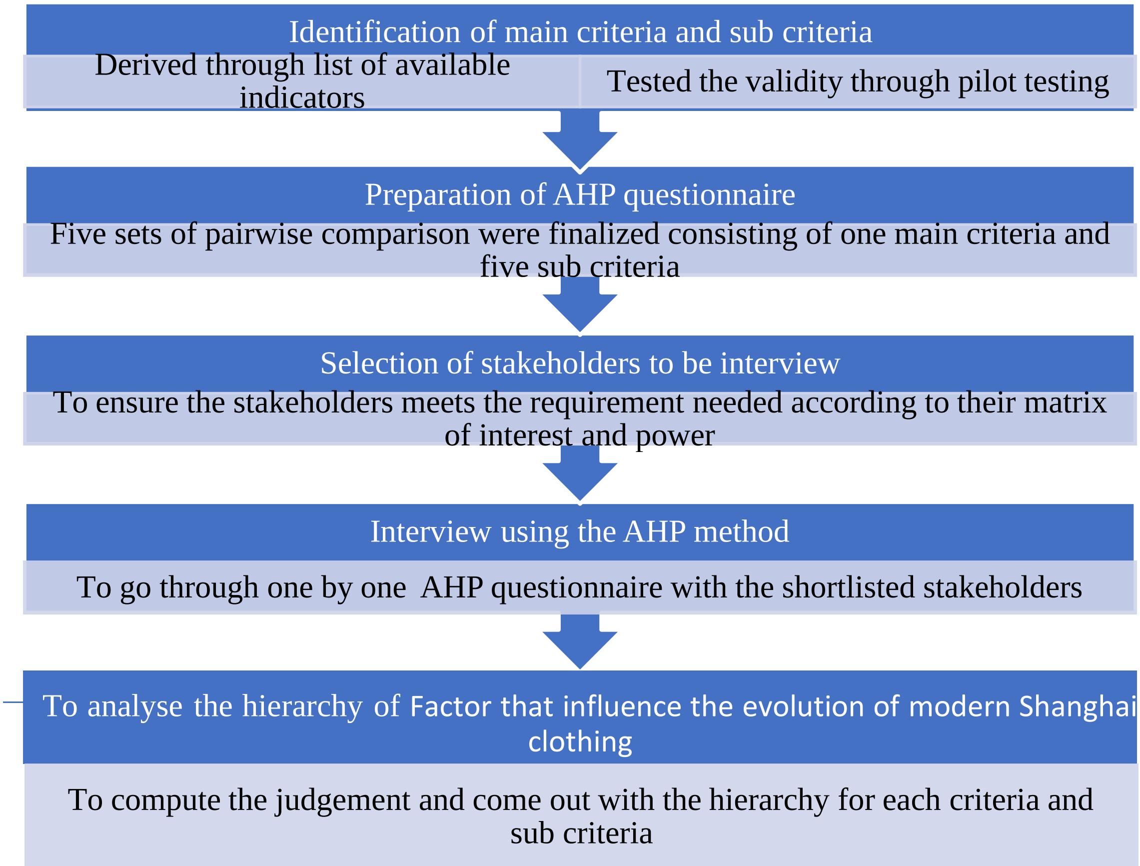
The Analytic Hierarchy Process (AHP) has been extensively applied in architecture anddesign to support complex decision-making processes (Bashier, F., 2019). As highlighted by Al Saggaf et al., (2020), AHP is a versatile decision-making tool, mirrors the human decision-making process, weighing both qualitative and quantitative factors to identify the best solution. It involves constructing a hierarchical structure that breaks down a complex problem into goals, criteria, and alternatives (Munier & Hontoria, 2021). Yang et al., (2022) highlight the pairwise comparisons are then used to assess the relative importance of these elements. This method is scalable, systematic and includes a consistency check to ensure reliable decision-making. Previous studies have utilized AHP to access the impact of design variables on criteria like cost and material efficiency. Other studies have combined AHP with the Likert scale to evaluate the performance of urban complexes after their use (Al-Saggaf et al., 2020, Hong et al., 2024; Qin et al., 2021; Cernikovaite et al., 2021 and Wu et al., 2024).

In sustainable building design, AHP helps prioritize energy-efficient alternatives and select sustainablematerials based on factors like environmental impact, cost, and durability. Urban planning benefits from AHP in site selection and land use planning by balancing economic development,environmental sustainability, and social equity. Architects use AHP to evaluate design concepts and facade options, considering aesthetics, functionality, and cost. It aids in buildingperformance evaluations, including post-occupancy assessments and green building certifications. Heritage conservation efforts employ AHP to prioritize restoration projects and select appropriate materials. In interior design, AHP facilitates decisions on furniture and lighting by weighing comfort, durability, and aesthetics. Infrastructure projects, such as bridge design and transportation systems, utilize AHP to balance structural integrity, cost, and environmental impact. Additionally, smart cities and IoT integrations benefit from AHP by evaluating smart technologies and infrastructure setups, ensuring energy savings, user convenience, and scalability. These applications highlight AHP's versatility in systematically evaluating multiple criteria for informed and balanced decision-making in architecture and design.

Its popularity in construction is due to its structured approach and ability to handle complex problem (xxx). AHP breaks down complex decisions into hierarchical structure, allowing for systematic analysis (xxx). It then compares elements within each level pairwise, assigning relative weights based on their importance. This method is scalable, systematic and includes a consistency check to ensure reliable decision-making (xxx). Previous studies have utilized AHP to access the impact of design variables on criteria like cost and material efficiency. Other studies have combined AHP with the Likert scale to evaluate the performance of urban complexes after their use (Al-Saggaf et al., 2020, Hong et al., 2024; Qin et al., 2021; Cernikovaite et al., 2021 and Wu et al., 2024).

2.0 Research Methodology

In the context of investigating the evaluation of sustainable design practices in architecture to provide new insights into the current stakeholder perception, the Analytic Hierarchy Process (AHP) can be used as a decision-making tool to prioritize and evaluate various factors that contribute to this evolution. Figure 1 shows how AHP had be applied in this study.



The data is collected through a questionnaire survey and analyzed with Super Decisions Software (SDS) using the AHP technique. The SDS is a user-friendly tool for constructing decision models by using a method called Analytic Network Process (ANP) that effectively dealing with complex decision-making processes. ANP breaks down problems into a hierarchical structure and allowing for a systematic factor evaluation. SuperDecision's intuitive interface and robust analysis capabilities make it valuable for various applications. It offers advantages like comprehensive analysis, systematic organization, sensitivity analysis, and user-friendliness (Pereira et al., 2024). While SDS is powerful tool, there are also other software that exist in the market with a similar feature such as Expert Choice, PROMETHEE, Smart Picker, Criterium Decision Plus, ERGO, and OnBalance (Baby, 2023). The choice of software depends on the specific needs of the decision-maker and the complexity of the problem.

Primary data for this study were the stakeholder interviews. They are the ones who involved directly and indirectly in the evaluation of sustainable design practices in Malaysia. Before proceeding with interviews, identification of the respondents is to be done first. Then, interviews were conducted to seek their preference on the factor that influence the evolution of sustainable design practices in Malaysia.

Hierarchical Structure: The decision problem can be structured hierarchically, with the main objective of finding the most sustainable design practices in Malaysia at the top. Below this, criteria can be identified that contribute to this evolution, such as energy efficiency, material selection, water conservation, indoor environmental quality and site and surrounding impact. Each criterion can then be further broken down into sub-criteria or factors that influence it.

Pairwise Comparisons: Decision-makers can then compare each pair of criteria or sub-criteria in the hierarchy with respect to their importance in the implementation of sustainable design practices. For example, they can compare the importance of energy efficiency versus material selection, or the influence of indoor environmental quality versus site and surrounding impact. These pairwise comparisons are typically done using a numerical scale to quantify the relative importance of each factor.

Deriving Priority Weights: The pairwise comparison judgments are used to derive priority weights for each criterion and sub-criterion in the hierarchy. These weights represent the relative importance of each factor in the implementation of sustainable design practices. Saaty's eigenvector method or other mathematical techniques can be used to calculate these weights.

Consistency Checking: AHP includes a consistency check to ensure that the pairwise comparison judgments are logical and coherent. If inconsistencies are found, adjustments can be made to the judgments to improve consistency.

AHP is a method to derive ratio scales from paired comparisons. By applying AHP in this manner, researchers can systematically evaluate the various factors contributing to the implementation of sustainable design practices and gain new insights into the current built environment trends. Perfect consistency indicates a consistency ratio (CR) value of zero. However, perfect consistency cannot be expected because humans are frequently biased and inconsistent in their subjective judgment due to the evolvement of new experiences, the season, or the time of the day. AHP allows some small inconsistencies in judgment. Therefore, it is considered acceptable for some inconsistency to occur to a certain degree. In this case, if the CR-value is less than 0.1, the pairwise comparison can be accepted as consistent.
After identifying the relevant indicators or criteria involved in the decision-making process, AHP is conducted in four steps (Flitter. H et al., 2013). Firstly, it is to perform pairwise comparisons among the criteria and sub-criteria. In each question, the respondents were asked to compare each objective with other objectives concerning the goal. This process also applies to the sub-objectives.

2.1 Sampling Procedure

The sample size for AHP studies is usually small since AHP needs experts in the field to be the respondents (Qureshi M.E. and Harrison S.R, 2003), and there are few experts available.

Identifying the right stakeholders is crucial in evaluating the factor that influence the Sustainable Design Practices in Architecture. For this study, a minimum of 2 respondents' stakeholders were required as representative from each specific group.

These stakeholders come from a diverse group of individuals and organizations who are directly or indirectly impacted by or have an interest in sustainable building practices (Heerwagen, J. & Zagreus, L. (2005). They were architects and designers, developers and builders, clients and property owners, government and regulatory bodies and environmental and sustainability consultants.

Architects and Designers act as the primary creators of building designs, responsible for incorporating sustainable practices. Their main interest is to be updated with best practices, innovative materials, and techniques to enhance sustainability in their projects (Iyengar, K. (2015).

Then we have the developers and builders whose role is to oversee the construction process, ensuring designs are implemented effectively. They will balance sustainability with cost-effectiveness, ensuring projects are completed on time and within budget while meeting sustainability standards.

The next target group is government and regulatory bodies. Their role is to establish and enforce building codes and sustainability regulations. These groups promote public health, safety, and welfare through sustainable building practices, offering incentives, and ensuring compliance with environmental laws.

Lastly there are the environmental and sustainability consultants. These respondents provide expertise on sustainable practices, materials, and technologies. They will advise on best practices, ensuring projects meet sustainability goals, and often participating in the certification process for standards like LEED or BREEAM. Involving a diverse range of stakeholders will give a more comprehensiveunderstanding of the factors influencing the sustainable Design Practices in Architecture can be achieved.

2.2 Pilot study

The pilot study was run to evaluate the design and method proposed for the analysis. It also may alert the researcher to issues that may adversely affect the study. Most importantly, it determines the feasibility of the study, so there will be no resources and time wasted at the end of the day (Van Teijlingen, E. R., & Hundley, V., 2001).

The set of questionnaires was prepared through content analysis and distributed to 20 respondents. It consists of two parts. Part A focuses on the respondent's demographics, while Part B looks for the factor that influence the implementation of sustainable design practices. The questionnaire consists of five constructs: energy efficiency, material selection, water conservation, indoor environmental quality and site and surrounding impact. All items were measured using a five-point Likert scale anchored at 1 (very least important) and 5 (very important).

The collected data underwent analysis using Cronbach's alpha to assess reliability, with an accepted value exceeding 0.70. In this study, the overall Cronbach's alpha was found to be 0.943, indicating that most items were deemed suitable for retention, as their removal would lead to a decrease in alpha. Each key factor exhibited excellent reliability, with alpha coefficients exceeding 0.7, where the resulting values ranged from 0.772 to 0.855.

Table 1 Cronbach's Alpha Value for Each Item

Item	No of Item	Cronbach's Alpha Value	Mean	Std Deviation
Energy Efficiency	4	0.837	31.36	3.672
Material Selection	4	0.796	21.73	2.798
Water Conservation	4	0.814	17.09	2.448
Indoor Environmental Quality	4	0.855	31.64	3.526
Site and Surrounding Impact	4	0.772	10.59	2.823

The developed instrument was validated using simple statistics and internal consistency reliability. The result indicates a high correlation between the items in the questionnaire. The five key elements are the most relevant factor that influence the sustainable design practices in Architecture. Then, these developed instruments should be further applied for data collection in the case study area.

2.3 Pairwise comparison

Pairwise comparison is executed to achieve a hierarchical structure of the factor influencing the Sustainable Design Practices in Architecture. A normalized score for each criterion is achieved based on the comparison matrix and table 2 shows the comparison matrix for the factor influencing the sustainable design practices in Architecture.

The Superdecisions software has been used to estimate the weights of the importance of the five primary objectives: energy efficiency, material selection, water conservation, indoor environmental quality, site and surrounding impact and their sub-objectives. It is also used to test for inconsistency between preferences within individual respondents' groups. Ultimately, the software helps to ranks the factor influencing the implementation of sustainable design practice

Table 2 Weightage for Sustainable Design Practices in Architecture

Factor	Normalized Score BE	Normalized Score SC	Normalized Score ED	Normalized Score TM	Normalized Score PC	Normalized Principal Eigen	
						Priority Vector	%
Energy Efficiency	0.300	0.266	0.258	0.316	0.315	0.291	29.11%
Material Selection	0.083	0.074	0.125	0.051	0.069	0.081	8.05%
Water Conservation	0.178	0.090	0.153	0.201	0.125	0.149	14.95%
Indoor Environmental Quality	0.206	0.312	0.165	0.217	0.246	0.229	22.93%
Site and Surrounding Impact	0.232	0.258	0.299	0.215	0.244	0.250	24.96%

Based on the table above, for the main criteria, the most important criterion for factor Sustainable Design Practices in Architecture is the Energy Efficiency, with the highest percentage of 29.11%. The least important is Material Selection, with only 8.05%. Local weight is the sum of all sub-criteria that is equivalent to 1. The ranking of each sub-criterion is noticeable when receiving the weights. Data synthesis for the AHP method is a multiplication of each ranking according to the priority of its criterion and sub-criterion and the sum of weights for each alternative to achieve the final priority. The mean value for each criterion is computed into super decisions. To achieve a consistent judgment, a consistency index is calculated for each comparisonmatrix where the inconsistency value must be less than 10% or 0.10. The smaller the varianceto the CI value, 0.1, the more consistent the judgment is. The CI for each matrix is shown below.

Table 3 Calculation for consistency ratio for the factor criteria.

	Criterion
Consistency Index (CI) CI = (λmax-n) / (n-1)	0.0302
Consistency Ratio CR= CI/RI	0.0269 3%
Results	Accepted

The CR are only used to check if the experts are consistent in their priority settings forpairwise comparison matrices. It shows a 3% consistency ratio value, meaning it is a consistentjudgment. The priorities vector derived from the comparison matrix is translated into a diagrammatic form to show the degree of the relative importance that one criterion has over another. The factors are arranged from highest to lowest (left to right). See figure 2 for the ranking summary.

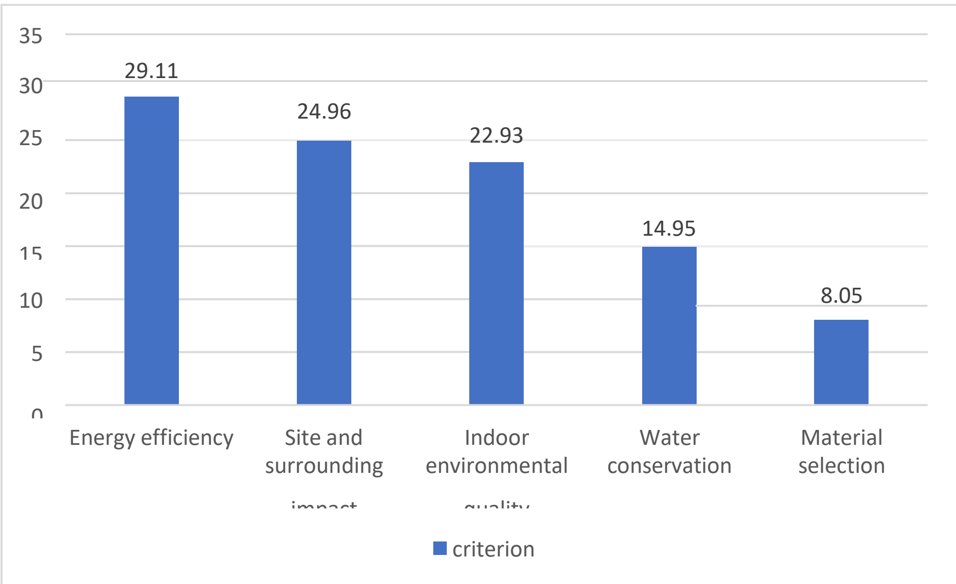


Figure 2 Ranking for factor of implementing sustainable design practices.

3.0 Practical Applications of the Findings

Implementing sustainable design practices in architecture has multifaceted implications for architects and designers, encompassing environmental, economic, social, regulatory, professional, and technological aspects. Sustainable design practices primarily aim to reduce the environmental impact of buildings. This involves using resources such as energy, water, and materials efficiently. By integrating renewable energy sources like solar and wind power, architects can significantly lower a building's carbon footprint. Additionally, sustainable design promotes the use of eco- friendly materials and construction methods that minimize waste. This not only helps preservenatural resources but also reduces pollution and habitat destruction, contributing to a healthier planet. The heat exchanged of the building envelope are responsible for 26% indicates the influence of thermal comfort between the building and its environment (Gupta & Deb, 2023). Factors like the building orientation, building wall and building envelope shape are susceptible to absorbing high amount of solar radiation (Chen et al., 2020; Qiu et al., 2021). Therefore, Gupta and Chakraborty (2021) mentioned for south-facing windows in hot climate regions are designed to maximize the light transmission and minimize on heat transmission. In contrast, while in cold climates, the windows allow heat transmission and insulate them against the cold. Al Saggaf et al., (2020) also studied that the window glazing can contributed about 60% of a building’s total energy consumption since windows are thermally poor in terms of energy efficiency (Liu et al., 2020). Hwang and Chen (2022) and Kamal (2020) investigated and reported there are different window systems across a building facade in Asian regions were conducted to identify the total energy consumption of buildings to optimize heating, lighting and cooling to maintain a comfortable interior environment.

Sustainable building practices by opting the material selection which help to reduce environmental impact, prioritizing safer material, while promote comfortable living, social benefits and economic impact (Sahlol et al., 2021; Qazi et al., 2021). These parameters guarantee that materials are energy-efficient and decrease waste and emissions to minimise a building's environmental impact. Additionally, by using such materials that require least energy to produce would further contribute to the sustainability goals whereby subsequently improve the health and well-being of human (Alwafi, 2022).

From an economic perspective, sustainable buildings often result in long-term financialbenefits. While the initial costs of sustainable features might be higher, these investments typically pay off through reduced operational costs, such as lower energy and water bills. Moreover, sustainable buildings tend to have higher market values and can attract environmentally conscious buyers and tenants, leading to increased property value. Governments also provide various incentives, including tax breaks and grants, for sustainablebuilding projects, making them financially attractive.

Sustainable design practices have profound social implications, particularly regarding occupant health and well-being. These designs emphasize indoor environmental quality, whichincludes better air quality, natural lighting, and comfortable thermal conditions. Such featurescontribute to healthier and more productive living and working environments. Furthermore, sustainable buildings can positively impact communities by fostering social equity and providing healthier living conditions. They also serve as educational tools, raising awareness about sustainability and encouraging responsible environmental behavior (Koutra, S., et. al., 2018).

Architects and designers must navigate a complex landscape of building codes and regulations that increasingly emphasize sustainability. Compliance with these regulations ensures that buildings meet specific energy efficiency and environmental standards. Achievingcertifications like LEED or BREEAM can provide formal recognition of a building’s sustainability, enhancing its marketability and credibility (Keitsch, M., 2012). LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method) are two of the most widely recognized certification systems for assessing the sustainability and environmental performance of buildings. According to Azhar, S., et.al. (2011), ensuring that sustainable design elements perform as expected is crucial for managing legal liabilities related to building performance and occupant health.

The shift towards sustainable design necessitates innovation and creativity among architects and designers. Sustainable projects often present unique challenges that require innovative solutions balancing aesthetics, functionality, and environmental responsibility (Koutra, S., et. al. 2018). This field also fosters interdisciplinary collaboration, as successful sustainable design often involves working with engineers, environmental consultants, and other professionals. Moreover, continuous learning and staying abreast of the latest sustainable practices, technologies, and materials are essential for maintaining relevance and expertise in the industry.

The integration of advanced technologies is a hallmark of sustainable design. Smart building technologies that optimize energy use, monitor performance, and enhance occupant comfort are becoming increasingly important. Innovations in materials science, such as high-performance, sustainable building materials, are influencing design choices and construction methods. As mentioned by Koziolek, H. (2011), Building Information Modeling (BIM) technology is revolutionizing sustainable design by providing detailed insights into a building's lifecycle, from design and construction to operation and maintenance, thereby improving efficiency and sustainability.

By understanding and addressing these implications, architects and designers can effectively implement sustainable design practices, leading to buildings that are not only environmentally responsible but also economically viable, socially beneficial, and technologically advanced.

3.1 Interpretation and Reporting of Findings

Most of the respondents for this survey have a minimum experience of 5 years up to 20 years. Measuring their involvement is essential to ensure they can comprehend the survey format. The measurement set for this study is ordinal as the aim is to achieve significant factors ranking.

The identification of energy efficiency as the most important criterion influencing the implementation of sustainable design practices reflects the critical role of reducing energy consumption and enhancing energy performance in achieving sustainability goals. This prioritization indicates a recognition of the significant environmental impact associated with energy use in buildings, including the reduction of greenhouse gas emissions and the reliance on non-renewable energy sources. It underscores the importance of adopting energy-efficient technologies and practices to minimize the ecological footprint of architectural designs. Furthermore, it suggests that stakeholders, including architects, planners, and policymakers, view energy efficiency as a fundamental aspect of sustainable development that contributes to both environmental preservation and long-term economic savings.

The site surrounding impact factor is identified as the second most important criterion influencing the implementation of sustainable design practices because it underscores the essential relationship between a building and its environment. Prioritizing site impact emphasizes the need to preserve natural habitats, minimize ecological disruption, and enhance biodiversity, which are vital for maintaining ecological balance. It also reflects the importance of integrating buildings harmoniously with their context, optimizing the use of natural resources such as sunlight and wind for energy efficiency. Additionally, considering site impact promotes social sustainability by fostering community connectivity, providing green spaces, and ensuring accessibility to amenities and public transportation. Effective site planning aids in efficient resource management, such as water conservation and land use, and enhances the building's resilience to environmental changes and natural hazards. Overall, this criterion highlights a holistic approach to sustainability, recognizing that the environmental, social, and economic aspects of the site are integral to the success of sustainable architectural design.

The result of this study is highly reliable since it is being validated through a scientifictheory where the consistency ratio (CR) falls in the right value range as suggested by Saaty (1980) and geometric consistency index (GCI) as suggested by Aguarón, J., & Moreno- Jiménez, J. M. (2003).

4.0 Recommendations for Future Research

Future research on evaluating sustainable design practices in architecture should focus on developing standardized evaluation criteria to ensure consistency and reduce subjectivity across studies. Longitudinal studies are essential to monitor the long-term performance of sustainable buildings, while comprehensive data collection on aspects such as energy usage, material sourcing, and lifecycle impacts can enhance the quality of assessments. The incorporation of advanced technologies like building information modeling (BIM), smart sensors, and IoT can improve real-time data accuracy. Additionally, conducting cross-regional and cross-climatic studies will help identify region-specific best practices. Economic analysis of sustainable design practices, alongside examining the impact of policies and regulations, will provide insights into financial viability and policy support. Exploring social and cultural factors, integrating interdisciplinary approaches, and investigating new sustainable materials and technologies will further enrich the research. Detailed case studies of exemplary sustainable buildings and effective community and stakeholder engagement are also crucial for identifying best practices and enhancing the relevance of sustainable design. Lastly, studying the resilience and adaptability of sustainable buildings to environmental changes, such as climate change, will ensure they remain effective in the long term.

5.0 Conclusion

In conclusion, the Sustainable Design Practices in Architecture is influenced by a list of factors that encompass both tangible and intangible aspects. It fosters interdisciplinary collaboration and innovation among professionals to address unique challenges while balancing aesthetics, functionality, and environmental responsibility. The decision-making process involved in understanding this evolution can benefit from methodologies like the Analytic Hierarchy Process (AHP), which allows for the systematic evaluation and prioritization of these factors. AHP's ability to numerically represent judgments and its analytical approach can aid in rationalizing complex decisions. Rapid advancements in sustainable technologies and materials can make it challenging to keep studies up to date. Practices considered sustainable today may become outdated as new innovations emerge. A comprehensive understanding of these factors, coupled with a structured decision-making approach like AHP, can provide valuable insights and considerations for stakeholders seeking to navigate the complexities of prioritizing the Sustainable Design Practices in Architecture.

6.0 References

Abhiram, Y., Das, A., & Sharma, K. K. (2021). Green composites for structural and non-structural applications: A review. *Materials today: proceedings, 44,* 2658-2664. https://doi.org/10.1016/j.matpr.2020.12.678

Abo El Kasem Ali, M. (2021). The role of green buildings in rationalizing energy consumption. *International Journal of Advances Engineering and Civil Research*, *1*(1), 21-37. https://doi.org/10.1016/j.jobe.2018.04.017

Adewale, B. A., Ogunbayo, B. F., Aigbavboa, C. O., & Ene, V. O. (2024). Evaluation of Green Design Strategies Adopted by Architects for Public Buildings in Nigeria. *Engineering Proceedings*, *76*(1), 24. https://doi.org/10.3390/engproc2024076024

Aguarón, J., & Moreno-Jiménez, J. M. (2003). The geometric consistency index: Approximated thresholds. *European journal of operational research, 147*(1), 137-145. https://doi.org/10.1016/S0377-2217(02)00255-2

Akadiri, P. O., & Olomolaiye, P. O. (2012). Development of sustainable assessment criteria for building materials selection. *Engineering, Construction and Architectural Management*, *19*(6), 666-687. https://doi.org/10.1108/09699981211277568

Aien, M., & Mahdavi, O. (2020). On the way of policy making to reduce the reliance of fossil fuels: Case study of Iran. *Sustainability*, *12*(24), 10606. https://doi.org/10.3390/su122410606

Almroth, B. C., & Athey, S. (2022). Toxic Chemicals in Textiles and the Role of Microplastic Fibres as a Source and Vector for Chemicals to the Environment. In *Polluting Textiles* (pp. 100-132). Routledge.

Al-Saggaf, A., Nasir, H., & Hegazy, T. (2020). An Analytical Hierarchy Process-based system to evaluate the life-cycle performance of buildings at early design stage. *Journal of Building Engineering*, *31*, 101364. https://doi.org/10.1016/j.jobe.2020.101364

Al-Saggaf, A., Taha, M., Hegazy, T., & Ahmed, H. (2020). Towards sustainable building design: the impact of architectural design features on cooling energy consumption and cost in Saudi Arabia. *Procedia Manufacturing*, *44*, 140-147. https://doi.org/10.1016/j.promfg.2020.02.215

Alwafi, A. A. (2022). Sustainable Material Selection Criteria Framework for Environmental Building Enhancement. *American Journal of Civil Engineering and Architecture*, *10*, 31-44. https://doi.org/10.12691/ajcea-10-1-5

Ashour, M., Mahdiyar, A., & Haron, S. H. (2021). A comprehensive review of deterrents to the practice of sustainable interior architecture and design. *Sustainability*, *13*(18), 10403. https://doi.org/10.3390/su131810403

Azhar, S., Carlton, W. A., Olsen, D., & Ahmad, I. (2011). Building information modeling for sustainable design and LEED® rating analysis. *Automation in construction*, *20*(2), 217- 224. https://doi.org/10.1016/j.autcon.2010.09.019

Baby, S. (2013). AHP modeling for multicriteria decision-making and to optimise strategies for protecting coastal landscape resources. *International Journal of Innovation, Management and Technology*, *4*(2), 218. https://doi.org/10.7763/IJIMT.2013.V4.395

Bashier, F. (2019). A Methodology for Architecture Theory and Practices Research: Design Practices Evaluation Studio. *European Journal of Sustainable Development*, *8*(4), 195- 195. https://doi.org/10.14207/ejsd.2019.v8n4p195

Buckley, N., Mills, G., Reinhart, C., & Berzolla, Z. M. (2021). Using urban building energy modelling (UBEM) to support the new European Union's Green Deal: Case study of Dublin Ireland. *Energy and Buildings*, *247*, 111115. https://doi.org/10.1016/j.enbuild.2021.111115

Černikovaitė, M.; Karazijienė, Ž.; Bivainienė, L.; Dambrava, V. Assessing Customer Preferences for Shopping Centers: Effects of Functional and Communication Factors. *Sustainability 2021, 13,* 3254. https://doi.org/10.3390/su13063254

Chen, S., Zhang, G., Xia, X., Setunge, S., & Shi, L. (2020). A review of internal and external influencing factors on energy efficiency design of buildings. *Energy and Buildings, 216,* 109944. https://doi.org/10.1016/j.enbuild.2020.109944

Conte, E., & Monno, V. (2012). Beyond the building centric approach: A vision for an integrated evaluation of sustainable buildings. *Environmental Impact Assessment Review, 34,* 31-40. https://doi.org/10.1016/j.eiar.2011.12.003

D'Amico, A., Pini, A., Zazzini, S., D'Alessandro, D., Leuzzi, G., & Currà, E. (2020). Modelling VOC emissions from building materials for healthy building design. *Sustainability, 13*(1), 184. https://doi.org/10.3390/su13010184

David, E., & Niculescu, V. C. (2021). Volatile organic compounds (VOCs) as environmental pollutants: Occurrence and mitigation using nanomaterials. *International journal of environmental research and public health, 18*(24), 13147. https://doi.org/10.3390/ijerph182413147

De Gaulmyn, C., & Dupre, K. (2019). Teaching sustainable design in architecture education: Critical review of Easy Approach for Sustainable and Environmental Design (EASED). *Frontiers of architectural research, 8*(2), 238-260. https://doi.org/10.1016/j.foar.2019.03.001

Dizdaroglu, D. (2022). Developing design criteria for sustainable urban parks. *Journal of contemporary urban affairs, 6*(1), 69-81. https://doi.org/10.25034/ijcua.2022.v6n1-7

Feria, M., & Amado, M. (2019). Architectural design: Sustainability in the decision-making process. *Buildings, 9*(5), 135. https://doi.org/10.3390/buildings9050135

Ford, B., & Wilson, R. (2006). Integration of sustainability in the design process of contemporary architectural practice. Proceedings PLEA, Geneva.

Grierson, D., & Moultrie, C. M. (2011). Architectural design principles and processes for sustainability: Towards a typology of sustainable building design. *Design Principles and Practices*, 623-634.
Grover, R., Emmitt, S., & Copping, A. (2020). Critical learning for sustainable architecture: Opportunities for design studio pedagogy. *Sustainable Cities and Society, 53,* 101876. https://doi.org/10.1016/j.scs.2019.101876

Gupta, J., & Chakraborty, M. (2021). Energy efficiency in buildings. In *Sustainable Fuel Technologies Handbook* (pp. 457-480). Academic Press.

Gupta, V., & Deb, C. (2023). Envelope design for low-energy buildings in the tropics: A review. *Renewable and Sustainable Energy Reviews, 186,* 113650. https://doi.org/10.1016/j.rser.2023.113650

Heerwagen, J. & Zagreus, L. (2005). The human factors of sustainable building design: post occupancy evaluation of the Philip Merrill Environmental Center.

Hong, X.; Li, S.; Chen, T.; Ji, X.; Song, X. Spatial performance evaluation and optimization of integrated aboveground and underground spaces in urban commercial complexes. J. Asian Arch. Build. *Journal of Asian Architecture and Building Engineering*, 1–27. http://dx.doi.org/10.1080/13467581.2024.2306367

Hwang, R. L., & Chen, W. A. (2022). Creating glazed facades performance map based on energy and thermal comfort perspective for office building design strategies in Asian hot-humid climate zone. *Applied Energy, 311,* 118689. https://doi.org/10.1016/j.apenergy.2022.118689

Iyengar, K. (2015). Sustainable architectural design: an overview. Routledge.

Kamal, M. A. (2020). Technological interventions in building facade system: Energy efficiency and environmental sustainability. *Architecture research, 10*(2), 45-53. https://doi.org/10.5923/j.arch.20201002.01

Keitsch, M. (2012). Sustainable architecture, design and housing. *Sustainable Development, 20*(3), 141-145. https://doi.org/10.1002/sd.1530

Khoshnava, S. M., Rostami, R., Mohamad Zin, R., Štreimikienė, D., Mardani, A., & Ismail, M. (2020). The role of green building materials in reducing environmental and human health impacts. *International Journal of Environmental Research and Public Health, 17*(7), 2589. https://doi.org/10.3390/ijerph17072589

Koutra, S., Becue, V., Gallas, M. A., & Ioakimidis, C. S. (2018). Towards the development of a net-zero energy district evaluation approach: A review of sustainable approaches and assessment tools. *Sustainable Cities and Society, 39,* 784-800. https://doi.org/10.1016/j.scs.2018.03.011

Koziolek, H. (2011, June). Sustainability evaluation of software architectures: a systematic review. In *Proceedings of the joint ACM SIGSOFT conference--QoSA and ACM SIGSOFT symposium--ISARCS on Quality of software architectures--QoSA and architecting critical systems--ISARCS* (pp. 3-12). https://doi.org/10.1145/2000259.2000263

Lami, I. M., & Mecca, B. (2020). Assessing social sustainability for achieving sustainable architecture. *Sustainability*, *13*(1), 142. https://doi.org/10.3390/su13010142

Lechner, N. (2014). *Heating, cooling, lighting: Sustainable design methods for architects.* John wiley & sons.

Li, S., Liu, L., & Peng, C. (2020). A review of performance-oriented architectural design and optimization in the context of sustainability: Dividends and challenges. *Sustainability*, *12*(4), 1427. https://doi.org/10.3390/su12041427

Liu, Q., & Ren, J. (2020). Research on the building energy efficiency design strategy of Chinese universities based on green performance analysis. *Energy and Buildings*, *224*, 110242. https://doi.org/10.1016/j.enbuild.2020.110242

Lopez, F. S. (2006). Architecture and nature at the end of the for sustainable design in architecture. Eco-architecture: *Harmonisation Between Architecture and Nature*, *86*, 23. Management, 19(6), 666-687. https://doi.org/10.2495/ARC060031

Markelj, J., Kitek Kuzman, M., Grošelj, P., & Zbašnik-Senegačnik, M. (2014). A Simplified Method for Evaluating Building Sustainability in the Early Design Phase for Architects *Sustainability*, *6*(12), 8775-8795. https://doi.org/10.3390/su6128775

Mba, E. J., Okeke, F. O., Igwe, A. E., Ozigbo, C. A., Oforji, P. I., & Ozigbo, I. W. (2024). Evolving trends and challenges in sustainable architectural design; a practice perspective. *Heliyon*. https://doi.org/10.1016/j.heliyon.2024.e39400

Mohammed, A. B. (2021). Sustainable design strategy optimizing green architecture path based on sustainability. *HBRC Journal*, *17*(1), 461-490. https://doi.org/10.1080/16874048.2021.1990572

Motawa, I., & Carter, K. (2013). Sustainable BIM-based evaluation of buildings. Procedia-Social and Behavioral Sciences, 74, 419-428. https://doi.org/10.1016/j.sbspro.2013.03.015

Munier, N., & Hontoria, E. (2021). Uses and Limitations of the AHP Method. Cham, Switzerland: *Springer International Publishing.*

Murtagh, N., Scott, L., & Fan, J. (2020). Sustainable and resilient construction: Current status and future challenges. *Journal of Cleaner Production*, *268*, 122264. https://doi.org/10.1016/j.jclepro.2020.122264

Olukoya, O. A., & Atanda, J. O. (2020). Assessing the social sustainability indicators in vernacular architecture—application of a green building assessment approach. *Environments*, *7*(9), 67. https://doi.org/10.3390/environments7090067

Pereira, V., Basilio, M. P., & Santos, C. H. T. S. H. T. (2024). Enhancing decision analysis with a large language model: pyDecision a comprehensive library of MCDA methods in Python. *arXiv preprint arXiv:2404.06370*. https://doi.org/10.48550/arXiv.2404.06370

Pons-Valladares, O., & Nikolic, J. (2020). Sustainable design, construction, refurbishment and restoration of architecture: A review. *Sustainability*, *12*(22), 9741. https://doi.org/10.3390/su12229741

Qin, Y.; Yao, M.; Shen, L.; Wang, Q. Comprehensive evaluation of functional diversity of urban commercial complexes based on dissipative structure theory and synergy theory: A case of SM city plaza in Xiamen, China. *Sustainability 2021*, *14*, 67. https://doi.org/10.3390/su14010067

Qiu, Z., Wang, J., Yu, B., Liao, L., & Li, J. (2021). Identification of passive solar design determinants in office building envelopes in hot and humid climates using data mining techniques. *Building and Environment*, *196*, 107566. https://doi.org/10.1016/j.buildenv.2020.107566

Qureshi, M. E., & Harrison, S. R. (2003). Application of the analytic hierarchy process to riparian revegetation policy options. *Small-scale forest economics, management and policy, 2,* 441-458.

Richter, M., Horn, W., Juritsch, E., Klinge, A., Radeljic, L., & Jann, O. (2021). Natural Building Materials for Interior Fitting and Refurbishment-What about Indoor Emissions?. Materials (Basel, Switzerland), 14(1), 234. https://doi.org/10.3390/ma14010234

Sözer, H., & Bekele, S. (2018). Evaluation of innovative sustainable design techniques from traditional architecture: a case study for the cold dry climatic region in Turkey. *Architectural Science Review*, *61*(3), 143-155. https://doi.org/10.1080/00038628.2018.1457509

Saaty, T. L., & Vargas, L. G. (2006). *Decision making with the analytic network process* (Vol. 282). Berlin, Germany: Springer Science+ Business Media, LLC.

Sahlol, D. G., Elbeltagi, E., Elzoughiby, M., & Abd Elrahman, M. (2021). Sustainable building materials assessment and selection using system dynamics. *Journal of Building Engineering*, *35*, 101978. https://doi.org/10.1016/j.jobe.2020.101978

Shajal, A. K. (2023). The Impact of Green Buildings on Urban Sustainability and Energy Consumption. *Journal of Sustainable Urban Futures*, *13*(6), 11–21. https://doi.org/10.1016/j.jobe.2020.101978

Van Teijlingen, E. R., Rennie, A. M., Hundley, V., & Graham, W. (2001). The importance of conducting and reporting pilot studies: the example of the Scottish Births Survey. Journal of advanced nursing, 34(3), 289-295. https://doi.org/10.1046/j.1365-2648.2001.01757.x

Wang, D., Xu, P. Y., An, B. W., & Guo, Q. P. (2024). Urban green infrastructure: bridging biodiversity conservation and sustainable urban development through adaptive management approach. *Frontiers in Ecology and Evolution*, *12*, 1440477. https://doi.org/10.3389/fevo.2024.1440477

Wu, H.; Yu, J.; Ai, S.; Zhou, P.; Chen, Y. Site Suitability Evaluation of a Large Commercial Complex Using an Improved Projection Pursuit Model. *Buildings 2024*, *14*, 1586. https://doi.org/10.3390/buildings1406158

Yang, W. C., Ri, J. B., Yang, J. Y., & Kim, J. S. (2022). Materials selection criteria weighting method using analytic hierarchy process (AHP) with simplest questionnaire and modifying method of inconsistent pairwise comparison matrix. Proceedings of the Institution of Mechanical Engineers, Part L: *Journal of Materials: Design and Applications*, *236*(1), 69-85. https://doi.org/10.1177/146442072110399

Zhang, L., Xu, M., Chen, H., Li, Y., & Chen, S. (2022). Globalization, green economy and environmental challenges: state of the art review for practical implications. *Frontiers in Environmental Science*, *10*, 870271. https://doi.org/10.3389/fenvs.2022.870271

Zhong, W., Schröder, T., & Bekkering, J. (2022). Biophilic design in architecture and its contributions to health, well-being, and sustainability: A critical review. *Frontiers of Architectural Research*, *11(*1), 114-141. https://doi.org/10.1016/j.foar.2021.07.006